two parents in all cases—or is there such a thing as sexual or racial prepotency? Do sports show a prepotency in breeding? What are the limits of inheritance—to what extent and to what degree are modifications of the soma transmissible? What are the laws and limits of crossing—the capacity of hybridization; the abnormal distribution—the patchwork intermingling—of parental characters in the body of the adult hybrid? Next there are the questions, allied to those of crossing, respecting the reciprocal effect between scion and stock in grafting. In how far is there such an effect and what is its cause? How about the phenomena of telegony in animals and of xeny in plants? Finally, there are the momentous questions concerning the relative importance of selection, of sporting with segregation of the aberrant individuals, of crossing and hybridization, and of self-adaptation in the origin of species.

Now, these problems are comparatively untouched. Yet they are recognized as immensely important. The reason why they have not been worked upon is largely because they don't lend themselves to investigation in the laboratory. For the successful study of these problems one needs, indeed, not an ordinary laboratory, but a farm or an extensive zoological reserve with hothouses, breeding ponds, insectaries and vivaria of various sorts. With such means at his disposal a naturalist might hope, during a long series of years, to answer many of these fundamental phylogenetic questions.

CURRENT PROBLEMS IN PLANT MORPHOLOGY.

RELATIONSHIP BETWEEN PTERIDOPHYTES AND GYMNOSPERMS.

THE year 1897 will always remain a memorable one in the annals of plant morphology on account of the illuminating discoveries made by Ikeno* and Hirase† of spermatozoids in Cycas and Gingko, by Webber‡ of spermatozoids in Zamia, by Belajeff § || and Webber ¶ Sm ** of important new facts in spermatogenesis, and by Bower†† of new evidence bearing upon the homologies of spore-producing members.

These investigations, with others somewhat less notable, have already resulted in some important modifications of taxonomic sequence. Engler‡‡ divides the subdivision Gymnospermæ into two series—(*a*) those with functional spermatozoids, including here the Cycadaceæ, Gingkoaceæ and fossil Bennettitaceæ and Cordaitaceæ, each order having also the rank of a class, and (*b*) those with reduced spermatozoids (*Spermakerne*), including the classes Coniferæ and Gnetales. Thus the aberrant genus Gingko has been removed from the order Taxaceæ of the Coniferæ and made the type of a new order, which constitutes a

* Ikeno, S. Vorlaüfige Mittheilungen über die Spermatozoiden bei Cycas revoluta. *Bot. Centralb.* 69:1–3. Ja. 1897.

† Hirase, S. Untersuchungen über das Verhalten des Pollens von Gingko biloba. *Bot. Centralb.* 69:33–35. Ja. 1897.

‡ Webber, H. J. Peculiar Structures occurring in the Pollen tube of Zamia. *Bot. Gaz.* 23: 458. *note.* Je. 1897.

§ Belajeff, W. Ueber den Nebenkern in Spermatogenen Zellen und die Spermatogenese bei den Farnkraüten. *Ber. Deutsch. Bot. Gesellsch.* 15: 337–339. 27 Jl. 1897.

|| Belajeff, W. Ueber die Spermatogenese bei den Schachtelhalmen. *Ber. Deutsch. Bot. Gesellsch.* 15:339–342. 27 Jl. 1897.

¶ Webber, H. J. The Development of the Antherozoids of Zamia. *Bot. Gaz.* 24:16–22. 31 Jl. 1897.

** Webber, H. J. Notes on the Fecundation of Zamia and the Pollen tube apparatus of Gingko. *Bot. Gaz.* 24:225–235. 30. O. 1897. (See also *Webber* ‡.)

†† Bower, F. O. Studies in the Morphology of Spore-producing members. The Marattiaceæ. Lond. 1897.

‡‡ Engler, A. Nachtrag zu Teil II.–IV. Pflanzenham. 341. 1897.

class by itself coördinate with the Coniferæ as a whole. Again, Engler's great division of Embryophyta Siphonogama is seen to be unfortunately named, precisely as was pointed out by the writer* as long ago as 1892, for apparently Salvinia has the same right to be described as siphonogamous that Zamia has, and the real difference between seed plants and archegoniates lower than the Cycads appears to be one that lies rather within the sphere of ecology than in that of morphology; the seed coming into existence, perhaps, in more than one phylum through symbiotic relationships established between sporophytic and gametophytic plants of a species. In brief, the group of Spermatophyta, while ecologically, is not morphologically, homogeneous.

Van Tieghem,† whose interesting innovations in the taxonomic arrangement of higher plants seem to have attracted less attention than their various merits deserve, founds a new type of what he terms basigamous fecundation (*basigamie*), upon the investigations by Webber of Zamia. A useful criticism of Van Tieghem's general notions regarding flowering plant taxonomy, as set forth in various papers since 1894, ‡ § || will be found in the work of Engler previously cited. It is interesting to note how the new light has been welcomed in both these taxonomic systems—Engler's, representing, upon the whole, the most modern development of conservative and slowly developed ideas, especially those of Eichler, and Van Tieghem's, representing, in a radical and novel manner, the influence of recent cytologic work on the embryo-sac and upon ovular development.

The importance of these discoveries upon spermatogenesis in particular have, however, much more than a formally taxonomic interest, for they open up in an inspiring way a number of cytological and morphological problems. They cast new light upon the vexed question of the sequences among Pteridophytes and make more certain the general acceptance of Bower's doctrines regarding the basal position of the Lycopodiaceæ rather than of the older view of Prantl, reaffirmed by Goebel, that Hymenophyllum-like ancestors connected the fernworts with the mossworts, or the view of Campbell, who sought in Ophioglossum the primitive type. For in the spermatogenesis of Zamia may be seen a recapitulation of spermatozoid improvement, and one learns how the biciliate form found in club mosses might, by the gradually increasing elongation of Webber's *blepharoplast*, or cilium-producing organ, be converted into the multiciliate form found in eusporangiate ferns and continued among higher ferns, in Cycads and in the Gingkoaceæ. Indubitably, then, the new investigations strengthen greatly the position that the biciliate spermatozoid forming Lycopodinæ are, as a class, lower than the Filicinæ with their multiciliate spermatozoids. Precisely the same result has been reached by investigations on the sporophytic side, notably by Bower in the paper cited and in others.*†

Regarding the phylogeny of Pteridophytes

* MacMillan, C. Metaspermæ of the Minn. Vall. 25. 1892.

† Van Tieghem, Ph. Sur une nouvelle sorte de Basigamie. *Journ. de Bot.* 11: 323-326. 16 Oct. 1897.

‡ Van Tieghem, Ph. Acrogamie et Basigamie. *Jour. de Bot.* 9:465-469. 16 D. 1895.

§ Van Tieghem, Ph. Sur les Phanérogames sans grains, etc. *Comptes Rend.* 124: 590-595. 22 Mr. 1897.

|| Van Tieghem, Ph. Classification nouvelle des Phanérogames. *Comptes Rend.* 124: 919-926. 3 My. 1897.

* Bower, F. O. Studies in the Morphology of Spore-producing Members. Equisetineæ and Lycopodineæ. Phil. Trans. Roy. Soc. Lond. 185 B. 473-572. 1894.

† Bower, F. O. Studies in the Morphology of Spore-producing Members. II. Ophioglossaceæ. London. 1896.

the following points may be regarded as settled:

1. *Phylloglossum drummondii* is the simplest known living Pteridophyte.

2. The fertile spike of Ophioglossum is derived by sterilization in transverse planes of a bilocular Tmesipteris-like sporangium.

3. *Tmesipteris tannensis* is, of known forms, the club moss nearest to the Filicinæ.

4. The sporangia-bearing leaves of Marattiaceæ and Leptosporangiate ferns homologize with the fertile spikes alone of Ophioglossum leaves.

5. In the sense in which sporophylls occur in Lycopodinæ they also occur in ferns among the Ophioglossaceæ, but in Marattiaceæ only the stipules remain to represent the old sporophyll lamina of archetypal ferns. In Leptosporangiate ferns even the stipular vestige has disappeared.

6. The Isœtaceæ, Salviniaceæ and Marsileaceæ are terminal groups.

7. Either seed-producing plants are of polyphyletic origin or the multiciliate type of spermatozoid has been developed in more than one branch of archegoniate plants.

Concerning the latter point it is proper to observe that most students of phylogeny have looked for the archetype of the Coniferæ in the vicinity of Selaginella. It will be noted that all genera of seed-producing plants known to produce spermatozoids do not produce biciliate, but multiciliate, spermatozoids. The embryogeny, however, of Lycopodinæ, notably of Selaginella, is much more similar to that of seed-producing plants than is the embryogeny of such ferns as Isœtes. With Isoetes and the Marattiaceæ the Cycads, however, show some striking points of similarity, and it may be that this group of seed-plants is allied rather with Filicinæ than with Lycopodinæ. If it be accepted that the prevalent pinnation of fern leaves is really of very profound significance and indicates the presence among their ancestral types of a Tmesipteris-like form with bilocular bilateral sporangium, capable of development into the fertile spike of Ophioglossum, it may also be held as probable that the pinnation of carpellary leaves of Cycas has a similar profound significance. On the other hand, the strobiloid features of the Zamiæ may also be fundamental and a Selaginella-like ancestor may, therefore, be proposed. In this case the multiciliate sperm of Gymnospermæ would be held to have an independent origin as compared with the multiciliate sperm of Filicinæ and Equisetinæ.

Of Equisetum, indeed, the archetype among living club-mosses would seem to be most closely reproduced in Psilotum with its radially trilocular synangia, and the difference between radia and bilateral synangia may be as important as indicated by Celakowski.* According to this student of phylogeny the radial type of synangium is the most ancient and is perpetuated in Gymnosperms as well as in Equisetinæ. There are, however, three types of synangia derived by sterilization of simple Lycopodium-like sporangia. These are as follows:

1. The radial type. Exemplified in Psilotum, Equisetum, Taxus.

2. The bilateral type. Exemplified in Tmesipteris and leading to the fertile spike of Ophioglossum and to the 'sporangiophyll' of Marattiaceæ and Leptosporangiate ferns and possibly to the carpels and stamens of Cycas.

3. The reticular type. Exemplified in Isoetes.

In Cycadaceæ the sporangial type is, from the pinnation of carpels, originally not trabecular, but bilateral, indicating either a Tmesipteris-like ancestor or an independent bilateral modification of the Selaginella

* Celakowski, L. J. Nachtrag zu meiner Schrift über die Gymnospermen. Engl. *Bot. Jhrb.* 24:202–231. 17 Ag. 1897.

type of unilocular sporangium. It is therefore impracticable to connect Cycas with Isoetes, on account of the sporangial structure, and either an independent development of heterospory must be assumed for the Cycadaceæ or they must be connected with the Coniferæ and traced back to Selaginella. That is, the evidence on the whole points to an independent deve opment in Cycadaceæ, and also probably in Gingkoaceæ, of multiciliate spermatozoids. This conclusion is borne out by the marked peculiarities of Cycad and Gingko spermatozoids as described by Ikeno, Hirase and Webber, although important resemblances between the development of the spermatozoid in Zamia, as described by Webber, and in Equisetum, as described by Belajeff, must be conceded.

The researches most needed at present are upon the genesis of the sperm-nucleus in Coniferæ and Gnetales to discover whether bodies which might be regarded as reduced blepharoplasts are present, and if so whether they indicate a multiciliate or biciliate spermatozoid in primitive Taxaceæ.

In general, it may be said that the polyphyletic theory of the origin of the gymnosperms is strengthened by the new researches, but it remains more difficult than before to include Isoetes-like forms among the probable ancestors of seed-plants. In addition, the very considerable differences between gymnospermous and angiospermous seeds arising from the wide variance in endosperm formation, together with the singular inversion (?) of the female plant in VanTieghem's Basigameæ and the suppression of the ovule in his Inovuleæ and of the nucellus in the Innucelleæ, together justify the view that the Spermatophyta is not a homogeneous group, but is purely ecological, comprising groups of widely different phylogeny, but, in general, similar adaptations arising under what I have previously termed symbiotic alternation of generations.

Conway MacMillan.

PALEONTOLOGICAL NOTES.

Among the recent papers of Mr. A. Smith Woodward, of the British Museum, are several matters of general interest in paleontology. Referring to Professor Marsh's discussion at Ipswich of the 'Jurassic Age of the Wealden Vertebrate Fauna,' Mr. Woodward has listed the Wealden fishes very carefully, and concludes as follows:*

"The result is, therefore, that all the known English Wealden fishes are survivors of typically Jurassic genera, except *Neorhombolepis* and *Cœlodus*, and these are their little-modified representatives. None but *Belonostomus* appear to range throughout the Cretaceous. In fact, the Wealden estuary seems to have been the last refuge of the Jurassic marine fish fauna in this part of the world, not invaded even by stragglers from the dominant race of higher fishes which characterized all the seas of the Cretaceous period. The Wealden river drained a land where a typically Jurassic flora flourished; the only two known Mammalian teeth from the Wealden resemble those of a Purbeckian genus, and now it is clear that the fishes agree both with these and the reptiles in their alliance with the life of the Jurassic era."

The second note relates to the occurrence of a gigantic Pterodactyl in the Cretaceous of Bahia, Brazil, and concludes with the following note:†

"Not being able to determine the genus of the Brazilian Cretaceous Pterodactyl, it is equally impossible to estimate the size of the skull or the animal itself from a single bone. There is too much variation from the proportions of the snout and the relative dimensions of the head among Pterodactyls to admit of any such induction. To judge by Marsh's figure of the skull of *Pteranodon*, however, the Brazilian form must have even exceeded in size the gigantic species of this North American genus, of which the head sometimes attains a length of four feet."

* 'On the Affinities of the English Wealden Fish-Fauna.' *Geol. Mag.*, Vol. III., No. 380, p. 69.

† 'On the Quadrate Bone of a Gigantic Pterodactyl,' etc. *Annals and Magazine of Natural History*, Ser. 6, Vol. XVII., 1896.